THE DETERMINATION OF THE FUNCTIONAL CAPACITY OF THE KIDNEYS.

BY ALBERT ASHTON BERG, M.D.,

OF NEW YORK,

Adjunct Surgeon to the Mount Sinai Hospital.

THE determination of the combined and individual functionating power of the kidneys is one of the most important considerations connected with the modern treatment of surgical diseases of these organs. The problem is a threefold one. Firstly, what is the combined work of the kidneys; secondly, what part of the total work is each organ doing; and thirdly, what work can each one do, if its fellow is removed or seriously injured,—*i.e.*, what is the potential functional capacity of each organ?

This last bears no constant relation to the former. Thus, it is not at all uncommon for a healthy kidney that is potentially able to perform the work of both organs to do temporary insufficient work because of a diseased condition of its fellow; and, *vice versa*, kidneys that are doing enough work may functionate altogether insufficiently when one or both of them are subjected to an incisive surgical procedure.

Experience has taught us that a single healthy kidney usually has the potentiality for doing work that is sufficient for the needs of the body, and furthermore that if the functional power of such an organ is hindered a removal of the cause thereof will be followed by a complete resumption of its sufficient functional work. On the other hand, we have also learned that a considerably diseased kidney has not the potential capacity of doing the entire work of the body. Whenever, therefore, a nephrectomy is contemplated it is of the utmost importance to determine the health or disease of the other organ. If the urine which is drawn from the latter by aseptic ureteral catheter shows it to be healthy the operation

may be proceeded with, even though its functional capacity is for the time being insufficient, for such an organ will manifest sufficient functional capacity when its diseased fellow is removed; if, on the other hand, the urine from the remaining kidney points to extensive disease therein, all incisive procedures upon the more diseased side should be abstained from, even though the functional capacity of the two organs at the time of our examination is a sufficient one.

The combined work of the kidneys is determined from the cryoscopic index of the blood,—*i. e.*, its freezing-point, and from the amount of urea which is eliminated in the urine in twenty-four hours; and the work of the individual organs is ascertained from the percentage of urea in the individual urines, from the amount of sugar and chromogen in each urine after a hypodermic injection of phloridzin and methylene blue respectively, and from the cryoscopic index,—*i.e.*, the freezing-point of the individual urines.

As the work of a kidney corresponds to the amount of secreting parenchyma it contains a comparison of the work done by the two organs will often indicate which one is diseased and if both are affected it will reveal which is the more extensively involved.

The Cryoscopic Index of the Blood.—The duty of the kidneys is to eliminate from the blood the waste products of tissue metabolism. In comparison with the other emunctories they are by far the most active, and if they functionate insufficiently these waste materials will accumulate in the blood and increase its molecular concentration. The determination of the latter, then, should give us information of the work that is being done by the kidneys. To ascertain the molecular concentration of a fluid we find out its freezing-point,—*i.e.*, its cryoscopic index, for this is directly proportionate to the number of molecules the fluid holds in solution.

The normal freezing-point of the blood is 0.56° to 0.60° C. below that of distilled water, and of course the greater its concentration is the lower will this freezing-point be. Thus

with insufficient kidney function the freezing-point falls below 0.60° C., in one case of the writer, to 0.87° C. The first question that arises is how constant is the freezing-point of the blood with normal functionating kidneys and the next query is how reliable an index of insufficient combined kidney function is a depression of the freezing-point below the normal. In the first place, it is essential to remember that one-fourth of the total kidney-tissue is sufficient to perform the work of the kidneys and to maintain the freezing-point of the blood at its normal level. With this preliminary note, it may be said that with sufficient kidney function the freezing-point of the blood is fairly constant at 0.56° C.–0.60° C. below that of distilled water. There are fluctuations, however, and amongst the most common causes of these may be mentioned large intra-abdominal tumors especially of the kidneys; heart disease, insufficient oxidation of the blood from respiratory disease, and one-sided renal pain. In these conditions the freezing-point of the blood may fall far below its normal level, and yet there may be no disturbance in the sufficiency of the kidney action; due allowance must, therefore, be made in them for abnormal depression of the cryoscopic index. Again, a severe anæmia, which is common enough in kidney diseases, may prevent the freezing-point of the blood falling to that level which would correspond to its molecular concentration.

Thus one might meet with a case in which with considerable insufficiency on the part of the kidneys, the freezing-point of the blood is, nevertheless, near the normal because of the severe grade of anæmia that is present.

With the exception of the abnormalities due to the causes just mentioned, we may say that a normal freezing-point of the blood,—*i.e.*, 0.56° C. below that of distilled water, indicates sufficiency of kidney function. It does not by any means permit us to infer that the kidneys are entirely normal, nor that their function will be sufficient after incisive operations upon them. If we remember that one-fourth of the total kidney-tissue can thoroughly well perform the entire work

of the kidneys we will understand how it is that cases, in which the freezing-point of the blood was normal before operation, exhibited marked insufficiency of kidney action after operation. For in such cases the kidneys either did not possess the potentiality for increased work, a *sine qua non* for the remaining kidney if there is to be a successful issue after nephrectomy, or by the operation we destroyed or injured enough of the remaining working parenchyma to seriously interfere with the sufficiency of the kidney action.

Furthermore, if a normal cryoscopic index does not indicate a potentially sufficient organ, neither does an abnormally low freezing-point always indicate a potentially insufficient organ, for we have seen above that a potentially sufficient organ may be temporarily insufficient because of the disease of its fellow.

In other words, the cryoscopic index of the blood merely indicates the work that is being done by the renal organs. It teaches us nothing of the health or disease of the kidneys, for three-fourths of the total kidney-tissue may be destroyed and yet the remaining one-fourth will be sufficient to maintain the normal molecular concentration of the blood; nor does it afford an indication of their potential functionating power. Only in connection with the health or disease of the individual organs can the freezing-point of the blood be considered as a help in this latter respect. Thus, if one kidney is diseased and the other is healthy or not much affected a normal freezing-point of the blood would point to a potential functional sufficiency of the latter and would permit of our removing the diseased organ. But an abnormally depressed freezing-point is not under these conditions to be construed as evidence of the potential insufficiency of the remaining kidney and therefore to speak against the advisability of doing nephrectomy. Furthermore, if the separately collected urines show that both organs are more or less extensively affected, a normal cryoscopic index of the blood is not proof of the potential functional sufficiency of either organ, and in such cases we should refrain

from nephrectomy or from any severe operation upon the kidney parenchyma even though the freezing-point of the blood is normal.

The relation of the cryoscopic index of the blood to the potential function of the kidneys may be summed up as follows:

(1) A normal cryoscopic index of the blood when there is one healthy and one diseased kidney would indicate a potentially sufficient functional capacity of the sound organ and would warrant us in doing a nephrectomy.

(5) An abnormally low cryoscopic index of the blood when there is one healthy and one diseased kidney does not indicate potential insufficiency of the former for the function of this organ may be only temporarily impaired by the diseased fellow organ. In such cases nephrectomy may nevertheless be done safely.

(3) A normal cryoscopic index of the blood when there is one slightly diseased and one extensively diseased organ would usually point to a potentially sufficient functional capacity of the less diseased organ and would allow of our doing a nephrectomy or other operation upon the more affected kidney.

(4) A normal cryoscopic index of the blood when there is more or less extensive affection of both kidneys does *not* mean a potentially sufficient functional capacity of these organs, and does not permit of our removing one or even of incisively attacking either organ.. And, finally,

(5) An abnormally low cryoscopic index of the blood with more or less extensive disease of both kidneys indicates their potential insufficiency and strongly speaks against the advisability of doing any operation upon them.

The Cryoscopic Examination of the Urine.—The molecular concentration of the urine varying as it does normally between wide limits according to the functional activity of the kidneys, their nervous and circulatory conditions, and the amount of fluid that is ingested, causes its freezing-point to likewise fluctuate considerably. This makes the cryoscopic index of the urine of less value as an indication of the secretory activity of the kidneys.

The urine of healthy kidneys, under normal conditions of circulation and nervous influence, and moderate ingestion of fluids, freezes at 1.2° C. to 2.2° C. below distilled water. With renal insufficiency less molecules are eliminated from the blood and consequently the molecular concentration of the urine,—*i.e.*, the number of molecules it contains in solution diminishes and its freezing-point consequently rises,—*i.e.*, approaches nearer to that of distilled water. If after moderate ingestion of fluids and with no disturbed circulatory or nervous condition the freezing-point of the urine is less than 1° C. below that of distilled water, renal insufficiency may be assumed.

The cryoscopic index of the separated urines affords a clue to the functional activity of the individual organs. For if we compare the freezing-points of the separated urines, collected at the same time and under the same circulatory and nervous conditions, we can gain an idea of what proportion of the combined kidney work each organ is doing; and further, as the work which is performed depends largely on the amount of secreting tissue in the organ, we may by a comparison of the freezing-points of the separate urines ascertain the extent of disease in each kidney.

The combined individual functional activity of the kidneys can also be determined by estimating the percentage of urea in the combined urines and individual urines respectively. A healthy individual being on a mixed diet, and doing an average amount of exercise and work eliminates about 500 grains of urea in the twenty-four hours; patients in bed and on a fluid diet eliminate about 300–400 grains in the twenty-four hours. Any marked decrease below 300 grains per diem is to be taken as an indication of impaired functional activity of the kidneys. The comparison of the percentage of urea in the separated urines, just as the comparison of the cryoscopic index of the separated urines furnishes an indication of what proportion of the combined work each kidney is doing, and likewise enables us to draw an inference as to whether both organs are diseased, and if so which is the more extensively involved.

The comparative value of these methods for determining the functional activity of the kidneys is not at all settled. Casper and Kümmel maintain that the cryoscopic index of the blood and of the combined and separate urines furnishes the best indication of the functional activity of the kidneys, whereas Israel, Rovsing and others insist that these methods for determining the kidney function are altogether too uncertain and too unreliable. Rovsing depends upon the urea percentage in the combined and separated urines as an indication of the amount of work that is being done, and upon the analysis of the urine for evidence of the health or disease of the kidneys. He maintains that a kidney which secretes healthy urine, containing a normal percentage of urea, is functionally sufficient, and can be relied upon to satisfactorily perform the work of the body.

Casper and especially Kümmel would reject all cases for nephrectomy or major operation in which the freezing-point of the blood is below 60° C. But this arbitrary practise is as has been shown above, entirely unwarranted. Thus the writer has had several cases recover after nephrectomy, in which the freezing-point of the blood was below 0.60° C.,—*i.e.*, 0.63°, 0.65°, 0.67° C., and other surgeons have had similar experiences. On the other hand, it is wrong to entirely reject, as Israel and Rovsing do, the evidence of kidney function that cryoscopic examination of the blood and of the combined and separate urines furnishes. The data these afford, viewed in the proper light, are additional evidence of the work the renal organs are doing and of their potential functional power. There can be no doubt that the best results will be obtained if all the methods are used.

The practise of the writer is to catheterize both ureters and collect the urine separately from each kidney. This is then carefully examined. The cryoscopic index of the blood and of the separated urines, and the percentage of urea in the combined and separated urines is then ascertained and by study and comparison of the data thus afforded no difficulty is experienced in determining the health or disease of the individual

organs, their combined and individual functional capacity, and the extent of the disease in each organ.

The phloridzin and methylene blue tests for the determination of the functional capacity of the kidneys have the same underlying principles as the cryoscopic index and urea percentage of the individual urines. Of the two the phloridzin is the more rapid and reliable. These tests rest upon the fact that after a subcutaneous injection of phloridzin sugar is eliminated in the urine and after a hypodermic injection of methylene blue various chromogen bodies are excreted in the urine. To carry out the tests both ureters are simultaneously catheterized and then 0.005 gm. of phloridzin, or 0.05 gm. of methylene blue are injected subcutaneously. As healthy organs are supposed to eliminate from phloridzin and methylene blue the same amount of sugar and chromogen respectively in the same time, a comparison of the percentage of sugar or chromogen which is eliminated by each kidney during the same period should enable us to determine the extent of disease in each organ and the amount of working parenchyema which is present.

In the methylene blue test it is likewise important to determine the time the chromogen first appears in each urine, and the rapidity and duration of its elimination.

Neither of these last tests can be relied upon for determining the health or disease of the kidneys, nor do they afford reliable data of the potential functional power of these organs, or of their actual work.